REMOTE SENSING CENTRE

PARKLAND SELECTION IN MANITOBA
UTILIZING LANDSAT COMPUTER CLASSIFICATION

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TABLE OF CONTENTS

	Page
ABSTRACT	i
LIST OF FIGURES	iii
LIST OF TABLES	iv
ACKNOWLEDGEMENTS	v
1. INTRODUCTION	1
1.1 Objectives	3
2. GENERAL DESCRIPTION OF STUDY AREA	4
2.1 Location and Extent	4
2.2 History and Present Development	4
3. LAND DISTRICTS	6
3.1 Rice River Land District	8
3.2 Bloodvein River Land District	9
3.3 Dogskin Lake Land District	9
3.4 General Vegetation	10
4. CLASSIFICATION SYSTEM	11
4.1 Cover Type Classification System	11
5. CLASSIFICATION METHODOLOGY	13
5.1 Input Data	13
5.2 Geometric Corrections	13
5.3 Unsupervised Classification	18
5.4 Supervised Classification	20
5.5 Input Data	21
5.6 Interactive Training	26
5.7 Training Area Purification	27
5.8 Trial Classification of Training Area	27
5.9 Trial Classification of Sub Areas	29
5.10 Classification of Entire Project Area	33
5.11 Post Classification Filtering	34
5.12 Manual Theme Generation	34
5.13 Thematic Map Production	36
6. RESULTS	41
6.1 Tabular Summary	41
6.2 Mapping Accuracy Assessment	41
6.3 Class Breakdown of Results	44
7. DISCUSSION AND SUMMARY	47
8. RECOMMENDATIONS/FUTURE ACTIONS	53
REFERENCES	54
APPENDIX 1 - MEMORANDUM OF UNDERSTANDING	

ABSTRACT

PARKLAND SELECTION IN MANITOBA UTILIZING LANDSAT COMPUTER CLASSIFICATION

A vegetation cover mapping project was conducted for the east side of Lake Winnipeg to assess the region for suitability and location of future wilderness park development. The study area included approximately 20,760 square kilometres of land lying east of Lake Winnipeg up to the Ontario boundary and between latitudes 51-15-00 N to 52-50-00 N. The area is part of the central boreal upland region of Canada and is characterized by large, diverse expanses of conifer and deciduous vegetation and rugged bedrock which influences landscape.

The significance of black spruce (Picea mariana) to the forest industry and the local economy dictated that a key requirement of the project be the differentiation of black spruce and jack pine (Pinus banksiana)and the identification of the regional distribution of these species so that park boundaries could be located away from critical stands.

An unsupervised computes classifier program was utilized on both single and multi date LANDSAT imagery to assess how the spectral data clustered and to aid in selecting supervised training sites. Separation of the softwoods was not possible using the unsupervised classifier. The use of supervised classification techniques provided an overall mapping accuracy of 87% with a black spruce separation from jack pine accuracy of 75%.

The classification results were divided into six map sheets which were plotted onto colour output thematic maps at a scale of 1:125,000. The six maps of the study area were mosaiced and employed in final senior management deliberations of park configuration and are proving invaluable to discussions regarding overall management of areas peripheral to the park.

LIST OF FIGURES

Figure		page
1	Map of study area	5
2	Map of land districts	7
3	Flowchart of interactive digital image processing (DIP)	15
4	Forest inventory township map of Township 33 Range 15 East	22
5	Aerial photo of dense jack pine and treed rock	25
6	Band 5 vs band 7 scattergram of training area statistics (June 9, 1980 image)	32
7	Forest cover map - east side of Lake Winnipeg (south sheet)	39
8	Forest cover map - east side of Lake Winnipeg (north sheet)	40
9	Approximate boundary of proposed wilderness park as outlined by Parks Branch	51

LIST OF TABLES

Table		Page
1	Classification cover type description	11
2	Area listing for forest inventory township map	23
3	Tabular summary of classification	41
4	Confusion matrix for classification accuracy assessment	43

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1.0 INTRODUCTION

The Department of Natural Resources of the Government of Manitoba and the Department of Energy, Mines and Resources, Government of Canada, by means of a Memorandum of Understanding, entered into a joint remote sensing Technology Enhancement Program (T.E.P.) in 1982 (Appendix I). The purpose of the program was to demonstrate the value of remote sensing satellite technology in managing Manitoba's natural resources. Personnel from participating agencies also had an opportunity to broaden their knowledge in this technology. The program involved the use of a DIPIX Digital Analysis System (ARIES II). on loan from the Canada Centre for Remote Sensing (C.C.R.S.). The equipment was installed at the Manitoba Remote Sensing Centre in December, 1982 and remained until the duration of the agreement (to November, 1984).

In response to an invitation to participate in this program, the Parks Branch, Manitoba Department of Natural Resources, proposed that a vegetation cover study be undertaken for a restricted area on the east side of Lake Winnipeg. The Parks Branch wished to have current land cover maps to assess areas suitable for a wilderness park. This area of the province is known to have the highest range of representative natural attributes of any central boreal upland in Canada. The absence of any comprehensive land use/land cover map of the area greatly hampered identification of a specific park boundary. The need to minimize impact of any forestry operations in the region was also of critical importance in the planning process.

1. The mention of a company name does not imply endorsement of the product.

An investigation into currently available vegetation mapping data revealed that the area had been mapped (1:15,840) under the Provincial Forest Inventory Program between 1969 to 1976. It was determined that 240 inventory maps, each covering one township, would have been required for park planning purposes; far too many for a synoptic assessment of the region. The detail of these maps necessitates that cover types be shown by a "stand" number which must be referenced to a separate table for each of several hundred "cells" per map. To facilitate pattern recognition, each map would also have had to be hand coloured through a process of data synthesis. Numerous large wildfires had ravaged the study area since the inventory maps had been completed which impaired their accuracy. Neither the funds nor the time required to conventionally interpret, hand colour and mechanically or photographically reduce the resulting product from these township-size maps and produce a display-quality product.

Satellite derived remotely sensed data offered a possibility for rapid and up-to-date categorization of the region. Research and pilot projects conducted at the Canadian Forestry Service and elsewhere have demonstrated a potential for computer-aided processing of LANDSAT multispectral images to provide reconnaissance, first stage forest inventory maps. Kalensky, Moore, Campbell, Wilson and Scott (1981) indicated that the number and type of forest classes and the accuracy of the classification depended on the type of forest, date of remote sensing, quality of LANDSAT imagery, and data processing method. They also reported that the accuracy of forest classification from LANDSAT

data at the softwood-hardwood- mixedwood level should be in the range of 70% to 90% depending on the quality of image data and forest characteristics.

Pala and Jano (1981) concluded that digitally analyzed LANDSAT data were suitable for mapping broad land cover types. Beyond this level, classification accuracy rapidly deteriorated with an increase in the number of more specific classes.

1.1 Objectives

The objectives of this study were to:

1. integrate remote sensing technology into both the parkland selection process and resource monitoring of parklands in Manitoba,
2. increase local expertise and awareness of remote sensing as an additional viable and cost effective survey tool,
3. provide detailed thematic maps and area estimates for the main vegetation cover classes on the east side of Lake Winnipeg at a scale of 1:125,000 and
4. assess the usefullness of LANDSAT based thematic maps for examining of geographic components of a land surface for parkland location. By increasing local expertise in the use of remote sensing, other agencies working outside this project will have the opportunity to evalute the potential of using remote sensing and to share the derived information to meet their particular needs.

2.0 GENERAL DESCRIPTION OF STUDY AREA

2.1 Location And Extent

The study area covered that portion of Manitoba between the east side of Lake Winnipeg and the Manitoba-Ontario boundary between Latitude 51 18' - 52 50' N. The mapping operation involved 20,760 square kilometers. The location of the study area in eastern Manitoba is shown in Figure 1.

2.2 History And Present Development

Little development or settlement has taken place in the study area. The region was influenced by the fur trade during the 1700's, although most activity was close to established trading posts on river mouths along Lake Winnipeg. Several Indian Reserves were established by treaty with the native peoples and apart for these lands, the area is controlled by the Crown. Except for a winter road system which links the communities on the remote reserves for a few months each year, the only access to the land on the east side of the lake is by air or by water.

The remoteness of the area and the high recreational values inherent in its whitewater rivers have made the region a focus for public interest as a wilderness park for nearly twenty years. Recent identification of a large number of both rare and representative natural features in the area, which are collectively significant on a national scale, have heightened this interest.

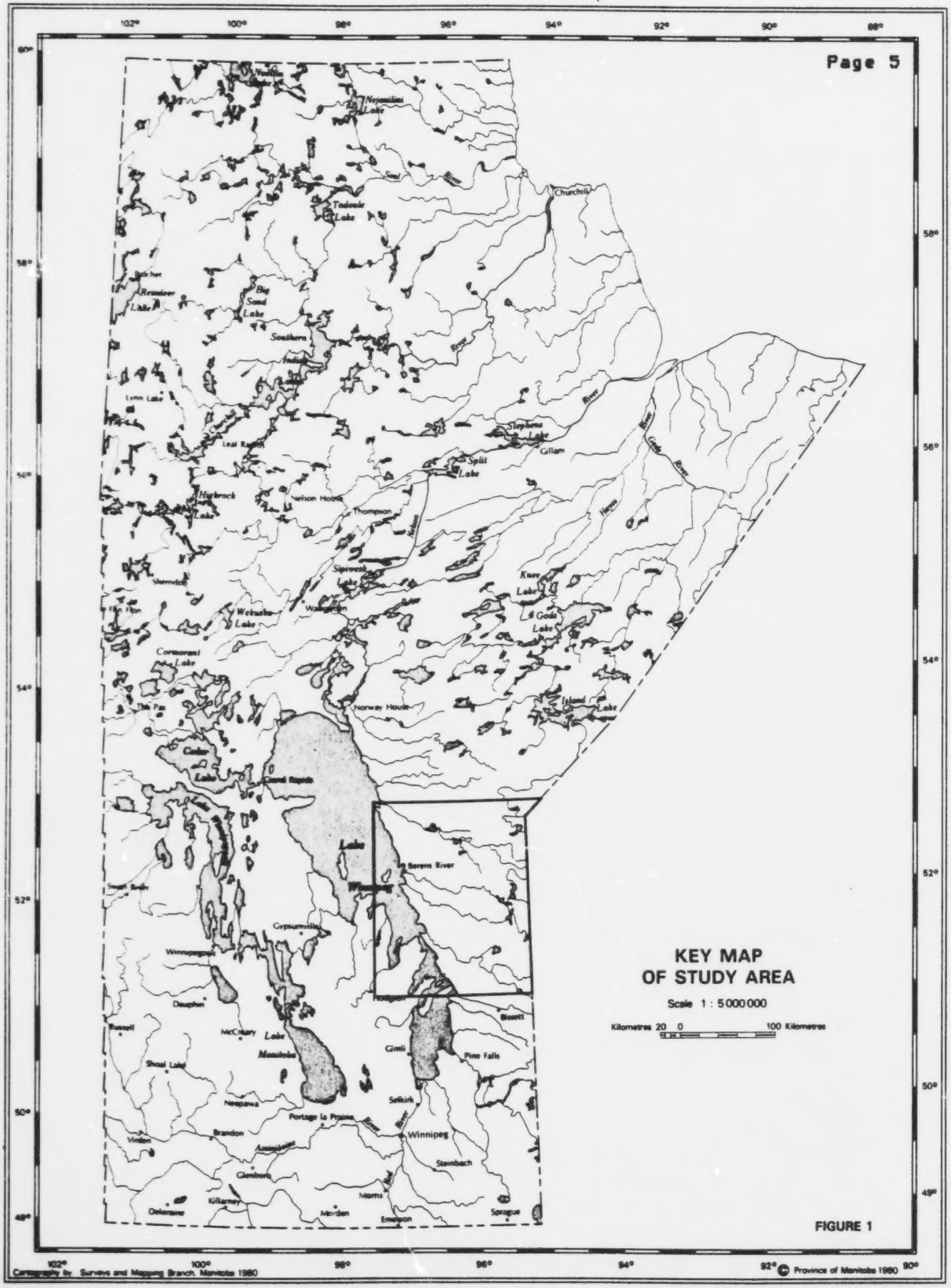


FIGURE 1

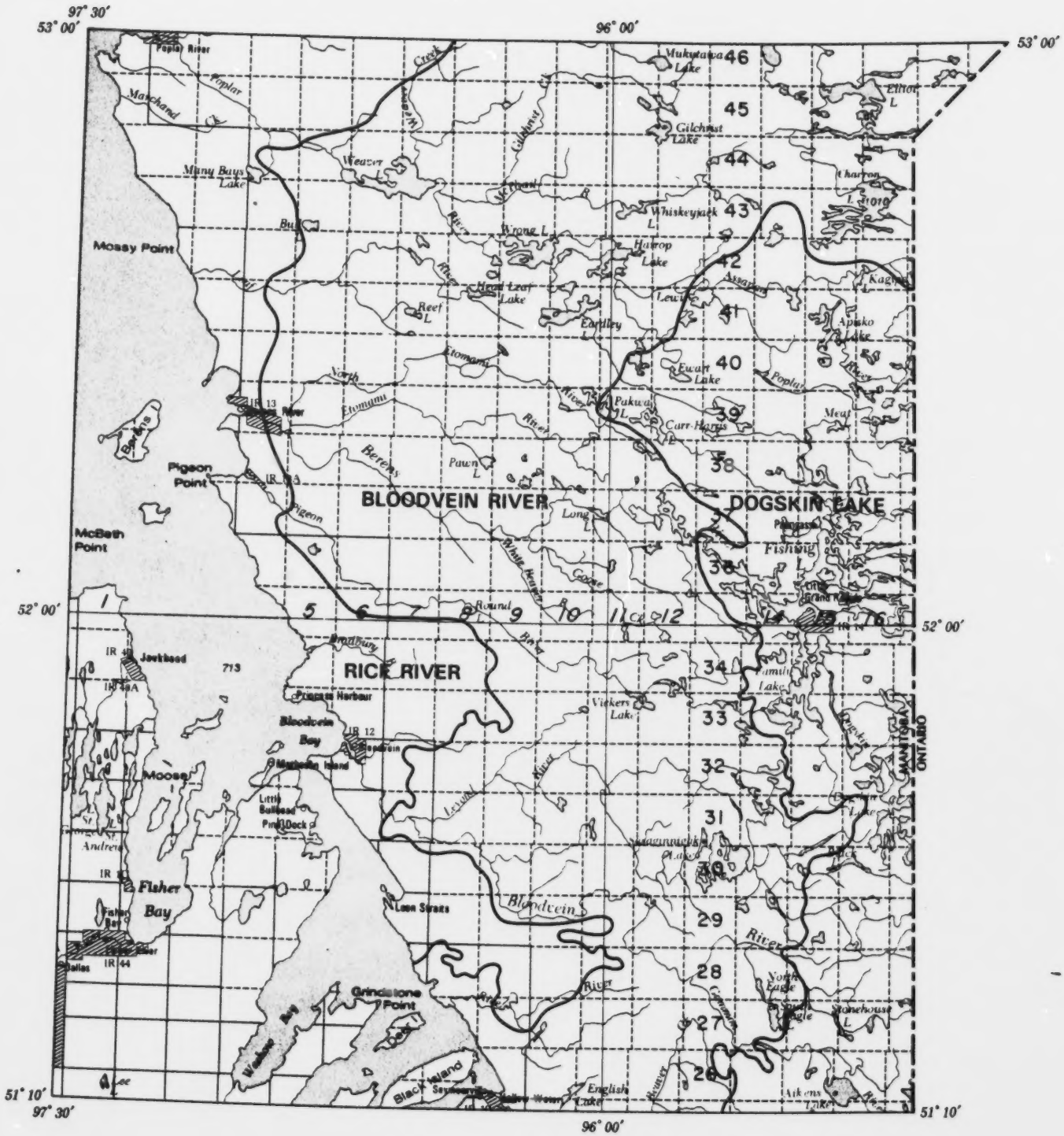
Cartography by Surveys and Mapping Branch, Manitoba 1980 © Province of Manitoba 1980

The region is also currently the focus of activites for several industries. Wood cutting operations are being conducted along many of the major rivers flowing into Lake Winnipeg. In recent years, this region has attracted considerable interest from the tourism sector. Several fishing lodges and fly-in outpost camps operate in the area. Trapping and domestic hunting by local people is carried on throughout the area. Commercial fishing takes place on Lake Winnipeg and Family Lake. Wild rice is gathered by lease holders in numerous lakes suitable for that purpose.

It was this background of varied land based uses, combined with a commitment to speed park designation that underlined the need for a comprehensive knowledge of land cover types to facilitate the decision making process.

3.0 LAND DISTRICTS

Physiographic characteristrics and the distribution of surficial deposits throughout the study area occupy the three Land Districts delineated on Figure 2. A Land District is characterized by a distinctive pattern of relief, geology, geomorphyology and associated vegetation. These three Land Districts, described in the following section, are summarized from Woo, V., G.F. Mills, H. Veldhuis and D.B. Forrester (1977)



MAP OF LAND DISTRICTS

Kilometres 10 0 10 20 30 40 Kilometres

FIGURE 2

3.1 Rice River Land District

This district occupies the western portion of the mapping area and appears as a dominantly poorly drained organic plain broken by occasional rock outcrops. The land surface (of the district) slopes gently westward, elevations decreasing from 270 m to 214 m a.s.l. at Lake Winnipeg. Topography over most of the district is very gently sloping to level and depressional. The organic terrain is dominated by large patterned fens with smaller areas of flat bog and blanket bog interrupted by low bedrock outcrops. The dominant organic materials are mesic fen peat underlain by calcareous lacustrine sediments. Shallow to deep clay deposits also occur at the surface adjacent to larger rivers and streams and along the east shore of Lake Winnipeg.

The Rice River District is characterized by relatively few, small lakes with smooth regular organic shorelines. Many large rivers and streams flow westward across the district, draining into Lake Winnipeg.

3.2 Bloodvein River Land District

This land district, occupying the central region of the study area, where elevations are generally below 330 m, adjoins the extensive organic deposits east of Lake Winnipeg at around 270 m a.s.l. The surface is dominated by gently to steeply sloping rugged bedrock outcrops which are only partially covered by veneers and

blankets of clayey lacustrine sediments. Pockets of sandy till and deep organic deposits may be found in association with the rock outcrop, but are much less common than lacustrine clay. In many cases a discontinuous veneer of noncalcareous till occurs in association with bedrock outcrops. Organic deposits are widely distributed and generally occur in the intervening depressions and valleys between outcrops. These organic deposits consist of deep (3 to 4 m) woody forest peat, sphagnum peat and minor areas of fen peat, all underlain by fine textured lacustrine sediments.

The numerous lakes of the district occupy irregular shaped depressions between areas of rock outcrop. Many rivers and streams flowing through the district follow an irregular drainage pattern toward Lake Winnipeg. The bedrock influence has deranged the drainage pattern and causes many rapids and low falls.

3.3 Dogskin Lake Land District

This land district extends east from approximately 330 m to 400 m a.s.l. along the Manitoba-Ontario boundary. The dominant features are bedrock knolls and ridges in which local relief of 20 to 30 metres are quite common. Very thin organic deposits occur in shallow enclosed depressions on the bedrock. However, the amount of organic soil found in association with the bedrock is variable as the peat may be completely destroyed by fire during prolonged droughts. Between bedrock outcrops, the intervening valleys and depressions are commonly occupied by bogs and fens. These organic deposits are usually underlain by fine lacustrine sediments.

This district contains an abundance of lakes, rivers and streams. The numerous water bodies of the area are characterized by very irregular bedrock controlled shorelines. All of the surface waters in the district flow westerly to Lake Winnipeg but in a very irregular pattern due to the bedrock influence.

3.4 General Vegetation

The prevailing vegetation on the flat, poorly drained land consists of forest patches of black spruce and tamarack (Larix laricina). Large, continuous growth stands of spruce predominatly occur within the Rice Lake Land District, adjacent to the east side of Lake Winnipeg. This district also supports expansive areas of treed bogs, fens and marshes. Other common boreal species, fir (Abies balsamifera), white birch (Betula papyrifera), and jackpine are also present. The pine frequenting the sandier soils as is usual but also extending to clay and silt soils after fire.

Good stands of white spruce (Picea glauca), trembling aspen (Populus tremuloides), and balsam poplar (Populus balsamifera), sometimes in mixture with fir and white birch, occur on the better-drained alluvial strips bordering rivers and creeks (Rowe, 1977).

4.0 CLASSIFICATION SYSTEM

4.1 Cover Type Classification System

The classes, or themes, and the grouping of classes derived from remotely sensed data are usually defined according to the users concept of the classification information. Naturally, the finer the division between classes, the more likely it is that class confusion will occur. The investigator must have a thorough knowledge of not only the capabilities but also the limitations of a four channel detector system such as the LANDSAT multi spectral scanner (MSS) in addition to the expected spectral responses of vegetation and other ground features. The classes chosen for this study were based on a literature search of previously conducted forestry mapping projects in Boreal areas.

The following classes, rated at the general reconnaissance level, were believed to best rationalize the complexity of the area within the limitations of the MSS sensor (Table 1).

TABLE 1

CLASSIFICATION COVER TYPE DESCRIPTION

1. Deciduous: Includes all hardwood species forming a component of 50% or greater. Dominant species are trembling aspen, balsam poplar and white birch.

2. Treed Rock: Areas of exposed bedrock with less than 50% tree cover. The dominant species is jackpine and occasional areas of scrub.

3. Water: All open water surfaces-lakes, rivers, streams and ponds.

4. Spruce: Dense stands of black spruce comprising 75% or more of the area.

5. Bare Rock: Exposed areas of bedrock with little or no vegetation.

6. Marsh: Grassy wet areas with standing or slowly moving water. Vegetation is comprised of grass and sedge sods, frequently interspersed with channels or pools of open water.

7. Treed Bogs: Peat-covered or peat-filled depressions with a high water table and a surface carpet of moss, chiefly sphagnum. The treed bogs have 25% or more canopy cover by trees that are more than one metre tall. The primary tree species is black spruce.

8. Burns: All areas having been recently burned over by wildfires. Included are areas of sporadic regeneration and pockets of unburnt tree stands.

9. Pine: Dense stands of jackpine comprising 75% or more of the area.

10. Cutover: Areas where commercial timber has been completely or partially removed by logging operations.

11. Urban: Built up areas resulting from community development.

5.0 CLASSIFICATION METHODOLOGY

5.1 Input Data

Three LANDSAT computer compatible tapes (CCT's) of track 33, each having a new image centre reformatted halfway between frames 23 and 24, were chosen for multi-temporal analysis. The dates of these images were: June 9, 1980, January 29, 1981 and May 17, 1981. To aid in the selection of ground verification sites, 32 forest inventory township maps were randomly selected from throughout the study area. To supplement and update the inventory maps, aerial photography obtained in 1976 at a scale of 1:50,000 was also incorporated into the ground verification process.

The LANDSAT imagery was analyzed with the aid of a DIPIX ARIES II digital analysis system located at the Manitoba Remote Sensing Centre. Both supervised and unsupervised classification techniques were tested. The methodology of digital image processing (DIP) used in the study is summarized by a flow chart (Figure 3). The DIP procedures can be divided into four groups according to their tasks: image to image registration of multi-date LANDSAT imagery; 2) geometric rectification and pixel size resampling of all image dates; 3) supervised and unsupervised classification; 4) post classification filtering and production of thematic maps.

5.2 Geometric Corrections

When utilizing LANDSAT CCT's the user may request that a scene of data be framed either according to the standard path and row numbers, or non-standard framing with the scene centre offset in the along-path

direction from that of the standard scenes. This is accomplished by specifying the desired centre latitude and longitude. The large study area occupied the equivalent of a full LANDSAT scene and was centred between two standard frame centres. In order to save on the costs of ordering two LANDSAT tapes for each year and having to deal with the project area being cut in half, the computer tapes were reframed midway between the standard image centres 23 and 24 of track 33.

Cal 3 tapes were chosen for analysis (Murphy, 1979). The standard geometric and radiometric corrections were applied to the data as part of the CCT generation process completed at the Prince Albert satellite receiving station. These corrections rectify problems associated with mirror velocity, panoramic distortion and earth curvature in the raw LANDSAT multispectral data. However, residual position error of up to 10 km still remains. A detailed description of CCT's has been published in the "Format Specifications For Canadian LANDSAT MSS System Corrected Computer Compatible Tape" by Murphy (1979).

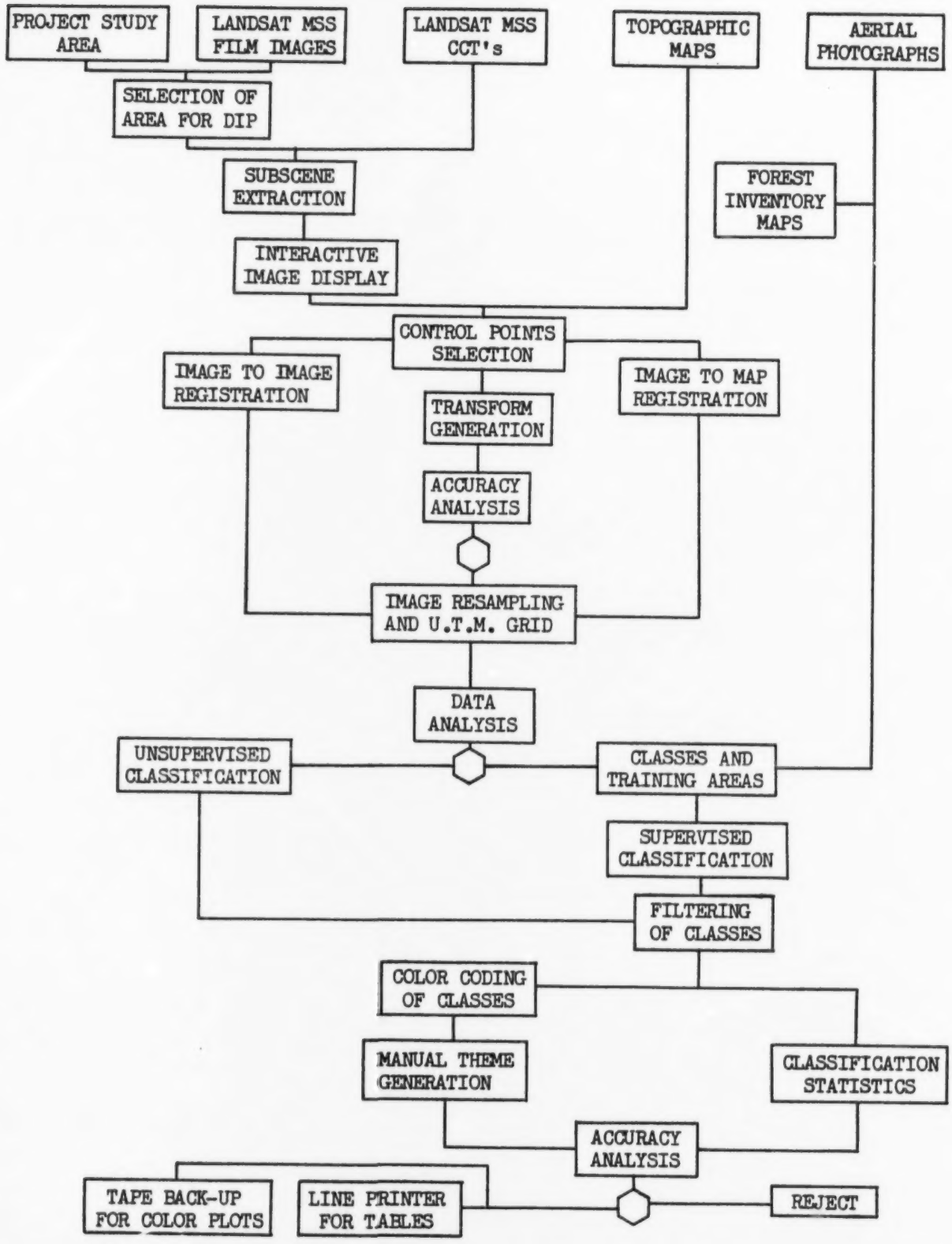


FIGURE 3: Flowchart of interactive digital image processing (DIP).

The precision geometric correction was accomplished with the ARIES system using the image to image and image-to-grid registration and resampling software. Initially, all the dates of satellite data were registered to each other. This was accomplished by designating the June 1980 image as the master to which the slave image from January 1981 was registered. The procedure involved loading two image dates simultaneously onto the T.V. monitor by way of split screen topology. Points such as lakes one pixel in size and small islands were chosen which were mutually identifiable on both images. Through interactive graphics, the cursor was positioned on the common point of each image. The computer then recorded the line and pixel coordinates for that point on each image. Absolute precision in identifying the common points is vital in order to achieve an accurate registration of the images. Approximately 30 points evenly distributed over the scene were selected.

A third order polynomial transformation was then calculated to transform one grid system to the other. A computer print out of the residual errors within the transformation was analyzed to assess mistakes in the selection of common points between the two images. If acceptable, the transform calculations are used to resample the slave image to the master image. The same procedure was applied to the May 1981 image to register it with the master.

The second phase in the geometric correction process involved the registration of all three images to the Universal Traverse Mercator Grid (UTM) system. Using 1:50,000 scale topographic maps, 26 control points evenly distributed over the study area were selected and identified on the LANDSAT digital data. UTM coordinates were then read from the topographic maps for these points and entered into the computer. Unfortunately, the LANDSAT scene passed through two UTM zones (13 and 14). Topographic maps on either side of the zone change have different UTM coordinate origins. This necessitated that the coordinates chosen from one zone had to be "forced" to the coordinate system of the other by way of a mathematical adjustment program.

The line and pixel coordinates were obtained automatically when control points were located with a cursor on the enlarged image displayed on the colour T.V. monitor. Coefficients of an affine transform were calculated from the UTM and image coordinates. An examination of the transform residuals revealed that the average coordinate error within the January 1981 image was 1.55 pixels while the other two image dates registered well with residual errors of less than one half a pixel. Several attempts were made to identify whether or not control point selection was causing the problems and many new ones were chosen. These efforts however, proved unsuccessful in improving the mean error in registration of this image.

The resampler program was run next and the original pixels (nominal ground resolution elements of 59 m x 79 m) were resampled to 50 m x 50 m. Furthermore, the LANDSAT scenes were reformatted to correspond to the coordinate system of the topographic maps. After completion of the geometric corrections, twelve bands of imagery from

the three years were available for analysis. For ease of data management, all twelve bands of data were prefixed with the same three character area name while the bands were labelled by year.

When the January 1981 image was overlayed with the June 1980 image, the effects of the 1.55 pixel residual error were obvious. Because of the mis- registration of this image, it was decided that too many problems would arise in multi temporal analysis, hence the image was abandoned. Piirvee and Braun (1978) experienced similar problems in the registration of a summer and winter image and concluded that a single affine transformation is not suitable for registering a full CCT. Subdividing the tape into many smaller blocks was suggested.

5.3 Unsupervised Classification

Because the study area occupied the majority of a full LANDSAT scene, two 500 x 500 pixel sub areas were selected for trial classifications. These sub areas were placed on each side of the project area and represented all cover types to be mapped. The trial classifications of the two test sub-areas included both unsupervised and supervised classification of single and multi date LANDSAT data. The rationale for using both classification techniques is as follows: Because extensive amounts of ground verification data were available from previously conducted Forest Inventory mapping work done in the early 1970's, along with high level aerial photography flown in 1976, it was decided that supervised classification of the whole project area would be the best choice. The unsupervised classification of the test sub areas was conducted in order to evaluate how the data

clustered and how separable the pre-chosen classes might be.

The ARIES II unsupervised classifier does not use field data for the determination of class statistics. Instead, it forms a histogram and identifies its spectral peaks from the multiband input data set. From the histograms of each band of data, a maxima table is calculated which shows the statistical parameters (mean values and standard deviations) for each peak. These values form the statistics for each class which can vary from 1 - 32 (classes). With ARIES, the number of categories (peaks) can be lowered by increasing the multiplier of standard deviation (merge factor). With the operator choosing the desired number of classes, the computer will calculate the necessary merge factor from the maxima table. For example, a maxima table may be reduced from 28 classes to 12 classes by this grouping technique. The fewer classes chosen, the more likely it is that similar ground features will be merged into a common class. In order to provide maximum separation, 16 classes were chosen from which signature files were generated. It is common practise to choose more clases than are required and then to manually merge classes where necessary at a later time.

Sixteen unsupervised signature files were first generated from the June 1980 image. A further sixteen were generated from all eight bands of LANDSAT data (June 1980 and May 1981) for purposes of a multi temporal classification.

Using these computer generated signature files, a maximum likelihood classification was performed on both the single date and two date image files respectively. The first trial classification of

the data provided sixteen classes. Visual analysis of the classification results allows the investigator to assess which classes should be combined. The ARIES software package allows for post classification class merging or separation should the initial trial classification not prove satisfactory. After combining certain signature files, on both the single and two date images, a second classification was performed on each test sub area. In this second iteration, nine signatures were generated for the classification.

The second set of classification results was examined for accuracy. Visual correlation with high level aerial photography revealed that the single date unsupervised classification was more accurate than the two date classification.

5.4 SUPERVISED CLASSIFICATION

5.5 Input Data

Two types of ground verification data, existing maps and aerial photos, were used to assist in selecting training sites for generating spectral signatures. The primary verification data utilized were forest inventory base maps at a scale of 1:63,360. Each covered one township (36 square miles). Because of the high degree of detail, these maps had to be synthesized. This involved grouping and colouring sites on the maps which were of common cover type. Each township inventory map was comprised of up to 400 or more individual stands. A forest stand is outlined on the basis of many attributes including: crown closure, species composition, site location and cutting class. A number is assigned to each stand on the map and

referenced back to a area listing for that township (Figure 4 - forest inventory township map and Table 2 - area listing).

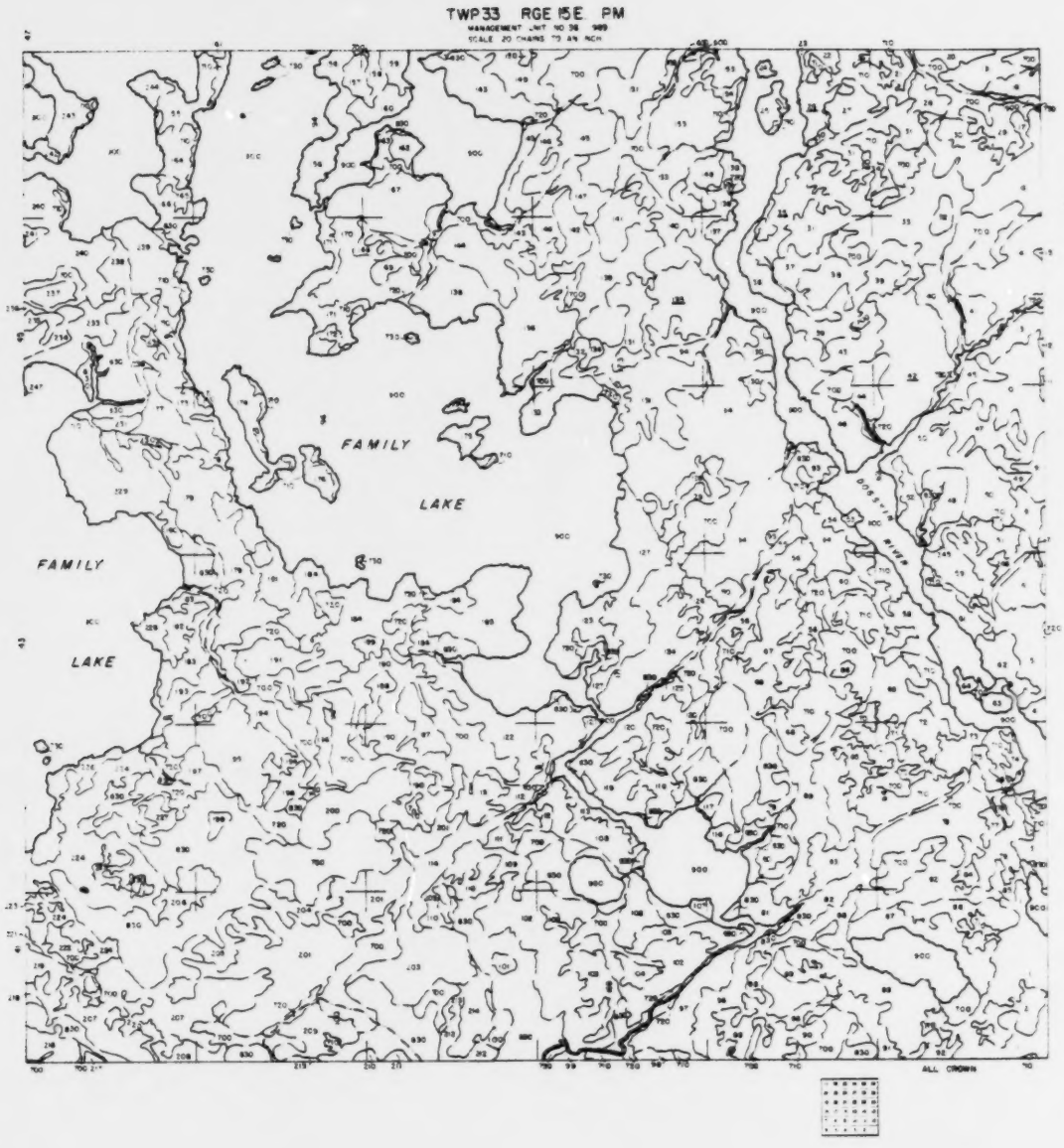


FIGURE 4: Forest Inventory Township Map of Township 33 Range 15 East

TABLE 2

AREA LISTING FOR MANAGEMENT UNIT 35 TOWNSHIP 31 RANGE 14 E

STAND	NUM	COVER TYPE	STAT	OWN	HECTARES	SPECIES COMP
1		06 2 3 3	2	1	127.6	JP7, BS2, TA1
2		13 2 2 4	2	1	11.7	BS10
3		06 1 3 4	2	1	43.7	JP6, BS3, TA1
4		04 1 3 4	2	1	10.1	JP10
5		04 2 3 3	2	1	8.5	JP10
6		04 1 3 4	2	1	1.2	JP9, BS1
7		04 2 3 3	2	1	22.3	JP10
8		04 1 3 4	2	1	16.6	JP8, TA1, BS1
9		13 2 3 3	2	1	10.9	BS10
10		04 2 3 3	2	1	6.5	JP9, TA1
11		06 2 3 2	2	1	60.7	JP7, BS2, TA1
12		04 2 4 3	2	1	44.1	JP8, BS2
13		04 2 3 2	2	1	18.6	JP8, BS1, TA1
14		06 1 3 4	2	1	40.1	JP7, BS2, TA1
15		46 1 2 4	2	1	5.3	JP4, TA3, BS2, WS1
16		06 2 2 3	2	1	39.7	JP7, BS2, TA1
17		13 2 2 4	2	1	7.3	BS10
18		04 2 4 3	2	1	14.6	JP8, BS2
19		14 1 4 3	2	1	36.4	BS3, TA2, JP2, WS1
20		13 2 3 3	2	1	9.7	BS10
21		13 1 2 4	2	1	6.1	BS10
22		06 1 3 3	2	1	34.8	JP6, TA2, BS2
23		04 2 3 3	2	1	23.9	JP9, BS1
24		06 1 3 3	2	1	13.8	JP7, BS2, TA1
25		06 1 2 3	2	1	19.4	JP7, BS2, TA1
26		04 2 2 3	2	1	2.4	JP8, BS2
27		06 2 2 3	2	1	40.1	JP6, BS2, TA2
28		04 1 2 3	2	1	4.9	JP9, BS1
29		13 2 2 4	2	1	8.5	BS10
30		13 2 2 4	2	1	4.0	BS10
31		04 1 2 4	2	1	30.4	JP8, BS1, TA1
32		04 2 2 3	2	1	15.4	JP9, TA1
33		04 1 2 3	2	1	19.4	JP8, TA1, BS1
34		04 2 2 3	2	1	0.8	JP9, TA1
35		04 2 2 3	2	1	5.7	JP9, TA1
36		04 2 2 3	2	1	12.1	JP9, TA1
37		04 1 3 3	2	1	39.3	JP9, TA1
38		04 1 2 3	2	1	9.7	JP8, TA2
39		04 2 3 3	2	1	6.9	JP10
40		04 1 2 3	2	1	19.0	JP8, TA2
41		04 2 2 3	2	1	0.4	JP6, TA3, BS1
42		44 1 3 3	2	1	12.9	JP6, TA3, BS1
43		13 2 2 4	2	1	2.4	BS10
44		44 1 3 3	2	1	3.2	JP6, TA3, BS1
45		44 1 2 4	2	1	29.1	JP6, TA3, BS1

Extreme care must be exercised in selecting and grouping of these stands for use in supervised training. For example, two stands may both be called jackpine, however, because of crown closure characteristics, the two stands may represent unique classes such as treed rock and dense jack pine (Figure 5). Black and white aerial photography at a scale of 1:50,000 and 1:15,840 were used as secondary input data in order to verify the training sites selected from the forest inventory maps.

In order to ensure a high level of homogeneity in the training sites on the inventory maps, only those stands which were over 70% pure were selected. This was later found to be of particular importance in separating spruce and jack pine.

Areas 'A' dense jack pine and 'B' treed rock are both labeled jack pine on the Forest Inventory Maps and recorded as having different crown closure characteristics. Care must be exercised when selecting training sites from the inventory maps to avoid class confusion.

FIGURE 5: Aerial photo of dense jack pine and treed rock.

5.6 Interactive Training

The selected ground verification sites were next identified on the LANDSAT digital image through the ARIES interactive supervised training task. This software task permits the operator to overlay the results of a previous classification onto the background image. Not only does this technique assist the operator in locating training sites but also provides some insight into which pixels are not characteristic within a supposedly homogeneous location. The results of the unsupervised classification were used for this purpose. The complex mix of cover types in the region combined with an absence of cultural features, made many pre-selected forest stand training areas difficult to locate within large, blanketed regions of forest.

The ARIES system used for this project operated on a 16 bit video memory field. Because the number of bits are dynamically allocated to the displayed channels, overlayed themes and training area segments (line graphics), the displayed image may visually degrade when many training areas and themes are displayed in the interactive training program. The degradation of the image compounds the problem of locating training sites. This problem can be somewhat circumvented by specifying fewer training areas or two channels of imagery instead of three. Better still would be the use of a 32 bit computer available as an option from the manufacturer.

5.7 Training Area Purification

Often manually drawn training areas contain isolated pixels which are not the same type as the majority of the training area. When the area is classified these pixels may remain unclassified or be assigned to another class. However, the feature values of these pixels were accumulated into the statistics of the training area causing inaccuracies in the signature parameters. These inaccuracies may have a significant effect on the classification.

Training area purification allows the operator to remove such pixels from the training area and/or the statistics. It performs a maximum likelihood thresholding function and displays those pixels which lie within an operator specified percentage of the mean. At the same time the statistics of this (reduced) set of pixels are accumulated again. The current signature and/or the training area can then be reset to match the displayed pixels. If the signature is reset, the new means and covariances are displayed and the new signature can optionally be written to a signature file.

5.8 Trial Classification Of Training Areas

A sub-routine of the interactive training program permits a maximum likelihood classification to be performed on any training area selected from those displayed on the T.V. monitor. The classification is based on a specified set of signatures, thresholds and "A priori" probabilities. The ARIES software calculates the parameters for the mean spectral vector, representing the class average value in multi- spectral space and the covariance matrix,

which is a measure of class dispersion. Calculations of the normal probability density functions are based on these two parameters. They approximate the data distribution in respective classes, thus providing models for sorting image pixels into the class to which they most probably belong (Kalensky, et al 1981). This procedure is known as the maximum - likelihood classification rule.

Each valid current signature can be included in the classification (up to the maximum number of themes specified at initialisation time). If the maximum number of themes is not reached using current signatures from training areas, additional signatures can be specified from disk files. A comparison of currently defined signatures from a training area with a previously defined set of signatures in a disk file is an example of how this option may be used. This procedure proves to be a very useful tool for a "quick look" at how the selected training areas and subsequent signatures will classify a local area in a final, overall classification, thereby providing an opportunity for the operator to immediately delete, add or re-purify existing training area segments.

The operator now proceeds to collect additional training area segments by displaying new sub-areas on the T.V. monitor and outlines their boundaries. Additional segments are added to existing training area files of the same name residing on the storage disc.

5.9 Trial Classification Of Sub Areas

After the operator is satisfied with the type and number of training areas selected, permanent signature files are generated through a task called "training statistics". Before the signatures are generated, scattergrams of the training areas were viewed in bands 5 and 7 to reveal potential areas of class confusion. However, because they only show two dimensional space, alone they are not absolute indicators.

Signature files were generated for both the June 1980 image and a combination of the latter and the May 1981 satellite image. For the multi date image combination, all eight bands of data were used to generate the signatures. Both sets of signatures were now used to classify the two 500 x 500 pixel sub areas as was done in the unsupervised trial classifications. An important consideration when performing a classification on eight bands of data is that it takes considerably longer computer processing times than for four bands because of the size of the matrix in which each pixel is examined to determine its best fit class. The amount of extra time for processing eight bands as compared to four is not simply a factor of two but rather it is related to the number of signatures and the degree of statistical overlap between them.

The results of the single date and multi date classifications were examined and compared to aerial photography and forest inventory maps. The single date classification provided very promising results while many problems were observed with the multi date combination. While it is not perfectly clear why the two date classification was

worse, it is very likely related to the following factors: The east side of Lake Winnipeg can have variations in the rate of spring thaw based on the proximity of a given location to the lake. Given the fact that the spring satellite image was taken on May 17, 1981, and covered a vast area considerably east of Lake Winnipeg, these variations were visibly noticeable on the data. Many lakes were completely or partially frozen while others were open. Variations in infrared response from deciduous stands were also observed. Sayn-Wittgenstein (1961) noted there are large differences between the dates when different trees leaf out. It often occurs that one tree species will be in full leaf, while the buds on others appear dormant. In a year with a long, cold spring the time that elapses between the leafing of different trees is particularly great. Differences in site, that is, mainly differences in local climate and soil, are very obvious reasons for variations in the date of leafing. On swampy locations and cool, north-facing slopes leafing will occur later than on warm and sunny sites.

It is believed that a lack of training sites to account for all the phenological differences in the tree flushing and various degrees of lake thawing accounted for the classification problems within the two date classification. This was indicated by unclassified areas on lake surfaces, confusion between tree species and occasional areas of open marsh classified as exposed rock due to ice and snow in the marsh. In order to judiciously expedite the project, the multi date classification was abandoned in favor of the single date June 1980 image.

Further training segments were added while others were modified and purified to improve the classification results of the single date June 1980 image. A second iteration of the two sub areas was run next with a new set of adjusted signature files. The results were quite satisfactory and led to the use of these signature files being used to classify the entire study area. An amalgamated scattergram of all selected signature file statistics is presented in Figure 6.

(1) Deciduous
(2) Treed Rock
(3) Water
(4) Spruce
(5) Bare Rock
(6) Marsh & Fens
(7) Treed Bog
(8) Recent Burn
(9) Jack Pine

FIGURE 6: Band 5 vs. band 7 scattergram of training area statistics (June 9, 1980 image).

5.10 Classification Of Entire Project Area

The entire project area, comprised of 8.62 million pixels per band, was classified using the maximum likelihood classification algorithm. The batch processing required 6.5 hours of computer time. This time factor graphically demonstrates the reason why small test sub-areas are processed first. The time required for classification of large images such as a full CCT could be considerably reduced if the raw data were not geometrically corrected and resampled to the smaller 50 x 50 metre pixel size. This resampling size produces 1.86 times more pixels than the original 59 x 79 pixels for the same size of project area. Alternatively, the investigator could geometrically correct and resample only the resulting classification thematic results. Instead of performing batch processing to geometrically correct and resample four bands of LANDSAT data, only one file would have to be corrected. The drawback to this technique, however, is that it is more difficult to locate features and orient yourself on the distorted, raw satellite image. Secondly, if the classification results are resampled alone at the end, the nearest neighbour algorithm must be used instead of cubic convolution. This produces a slightly more blocky image.

As is often the case, expermintation with small test sub blocks is not an exact indicator of how the entire project area may classify with the same signature files. The first classification of the entire area revealed certain inconsistencies which required slight

modification of the signature files to correct. A second classification run was performed which provided good results.

5.11 Post Classification Filtering

Post-classification filtering of the results was performed to eliminate small scattered pixel groups resulting from spectral anomalies located in broader, more homogeneous cover classes. The minimum area filter program can be explained by an example. If a minimum area filter were applied to a perfect classification which divided the region into land and water, all islands smaller than a certain area would become water and some small lakes would become land.

The program allows the operator to specify minimum size groups of pixels representing any theme which shall be allowed to remain. Those areas of each class that are less than the specified minimum are set to replaceable and then each replaceable area is eaten into equally from all sides by the surrounding pixels. The "eat-in depth" for these scattered pixels (which is a measure of how far into a more pure theme that scattered pixels may be changed) can also be specified. This technique removes the speckled effect which would normally occur in unfiltered thematic map production.

5.12 Manual Theme Generation

The manual theme generation program provides the capability to manually override or change classification results within a theme file. This technique was used to include wildfires which had ocurred

after the June 9, 1980 scene was imaged. The May 17, 1981 image contained several large burn areas which had to be shown on the final classification result. The procedures employed to facilitate this requirement are as follows. Because both image dates were registered, it was possible to view one band of data for one year combined with another band from the other year. It was found that by loading band 7 of the 1981 image through the red colour gun of the T.V. monitor and band 7 of the 1980 image through the green colour gun produced a unique red-blue shade which clearly identified the recent burns from the old ones. This two feature image was loaded into the interactive training program task and the perimeter of each missing burn was outlined as a training area. The manual theme task is next initiated. Within this task, the operator makes new theme assignments by using the training area file to identify areas of pure theme contained within a reference area. By requesting the "fill" mode, all pixels contained in a training area are assigned to a specified theme bit position at the same time changing all previously classified pixels inside the training area to a new classification (burn).

Manual theme assignments also prove very useful for outlining small urban areas. Frequently, it is desireable to sacrifice a small, insignificant class for the sake of improving another larger class. For example, an attempt was made to generate a signature for several small settlements. Because of the bright tones of the roadways, houses and exposed rock within these centres, considerable confusion occurred between this class and exposed rock. Rather than have incorrect scattered pixels groups from the urban class dispersed throughout the exposed bedrock areas, built up areas were manually

outlined and included into the classification results. This process took only one-half hour.

Manual theme assignments are also useful for "cosmetic" improvements of the classification results. Missing segments of rivers, lakes and a host of other cultural features may be added. A tedious process at best, however, considering that each manual theme assignment must be outlined by a closed polygon through the interactive movement of the cursor. The integration of a X-Y table digitizer would be very useful for these purposes. The digitizer is used in conjunction with a comprehensive cartography package available with the ARIES system. Maps or air photos can be placed on the digitizer and a polynomial transformation can be performed to register that product to the digital satellite image. Under cursor control of the digitizer, a one pixel wide line can be superimposed over the thematic data. Any type of cadastral information, soil zone boundaries, administrative boundaries, etc. could be very quickly added.

5.13 Thematic Map Production

A prime consideration in most resource mapping projects is outputting and presentation of the data. It has been the authors' experience that most resource managers and users of classification results, whether they be derived from satellite or other data, are much more concerned with the ability to use the data than how it was extracted. Central to this belief, to gain acceptance, maps must be easy to read with a concise legend and should have a readily understood reference system for locating features on the map.

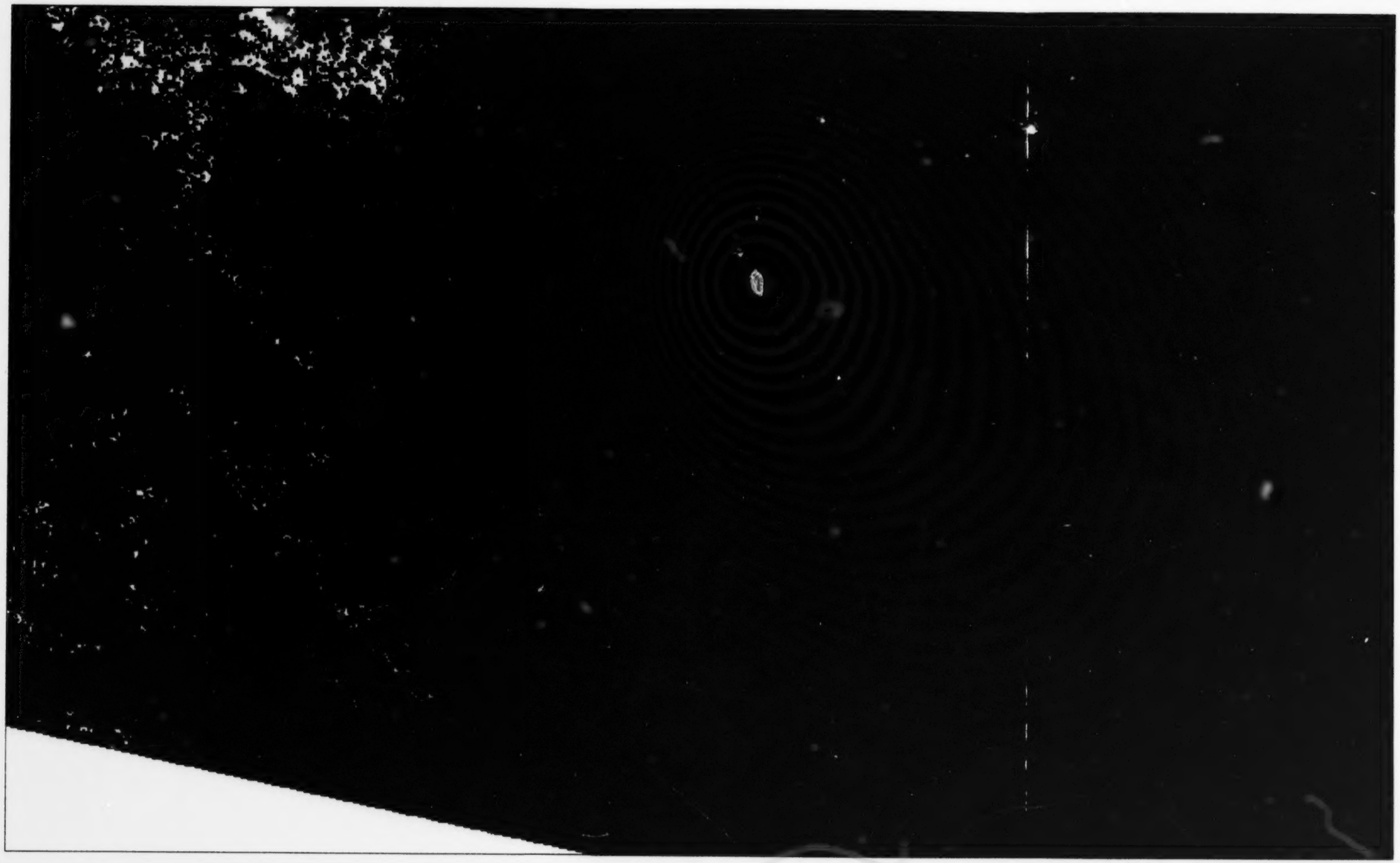
Various techniques are available to the user of satellite data to output his classification results. These range from photographing the screen with a 35 mm camera to elaborate electron beam image recorders to colour ink jet plotters. Unfortunately a colour output device often represents the price equal to the investment of the entire image analysis system. Recent developments, however, have led to the production of small, easy to maintain electrostatic colour plotters for under $20K.

A favorite of many satellite thematic map users has been colour maps produced on the Applicon ink jet colour plotter. Formatting at almost any scale and a variety of 32 colours make these maps extremely attractive. Output maps for this project were produced through the Applicon plotting method. This procedure requires the production of a specially formatted back-up computer tape of the classification results where the operator sets up the colour assignments to classes, adds legend, title and scale information. This process normally requires two hours of computer time for each map produced. The Applicon maps produced for the east side of Lake Winnipeg were at a scale of 1:125,000. The large study area had to be broken into six map sheets for presentation of the data at this scale.

A characteristic of colour plotter output maps is that of decimation, or the amount of data lost on the output map. The degree of decimation is directly related to the resolution of the plotter and the selected map scale. The Applicon plotter, for example, plots its pixels as 1 mm squares (which is the resolution of the plotter). This pixel size does not change in proportion to map scale. On a satellite image, made up of 50 m x 50 m pixels, one linear kilometer will be

spanned by 20 pixels. If a thematic map is produced at a scale of 1:250,000 that same kilometer on the map would only measure 4 mm. Because the plotter only produces pixels 1 mm square, only every fifth pixel and every fifth line of the original data could be shown at this scale. This represents a considerable data loss and must be taken into account when producing output maps. Alternatively, maps produced at a scale of 1:50,000 (1 kilometer = 20 mm on the map) will show every line and pixel.

The output maps illustrated in this report, were produced at a scale of 1:200,000 and furtherly reduced when they were colour separated for printing (Figure 7 and Figure 8).



DECIDUOUS
OPEN CONIFER
WATER
SPRUCE
BARE ROCK
MARSH AND FENS

FOREST COVER MAP-EAST SIDE LAKE WINNIPEG

COMPILED FROM SUPERVISED CLASSIFICATION OF A JUNE 9/80 LANDSAT IMAGE
PREPARED BY THE MANITOBA REMOTE SENSING CENTRE FOR PARKS BRANCH
THROUGH THE MRSC-CCRS TECHNOLOGY ENHANCEMENT PROGRAM
MARCH 1984

South Sheet

0 5 10 15 km

MULTICLASSIFIED UNCLASSIFIED

TREED BOGS
RECENT BURNS
DENSE MIXED CONIFER (MOSTLY PINE)
COMMUNITIES

FIGURE 7

DECIDUOUS
OPEN CONIFER
WATER
SPRUCE
BARE ROCK
MARSH AND FENS

FOREST COVER MAP-EAST SIDE LAKE WINNIPEG

COMPILED FROM SUPERVISED CLASSIFICATION OF A JUNE 9/80 LANDSAT IMAGE
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MARCH 1984

North Sheet

MULTICLASSIFIED
UNCLASSIFIED

TREED BOGS
RECENT BURNS
DENSE MIXED CONIFER (MOSTLY PINE)
COMMUNITIES

FIGURE 8

6.0 RESULTS

6.1 Tabular Summary

Statistical results for the number of pixels, hectares and percent coverage for each theme were calculated from the final, filtered classification and are presented in Table 3.

TABLE 3

Tabular Summary of Classification

Theme File 1 (ELWTTNEW1) AND Theme File 2 (ELWTTNEW2)

SUMMARY FOR FULL AREA CONTAINING 8615150.0 PIXELS

		PIXELS	HECTARES	PERCENT	COVER CLASS
File 1	Theme 1	439830	109957.5	5.1	DECIDUOUS
File 1	Theme 2	2075597	518899.3	24.1	OPEN CONIFER
File 1	Theme 3	1103040	275760.0	12.8	WATER
File 1	Theme 4	425489	106372.3	4.9	SPRUCE
File 1	Theme 5	258238	64559.5	3.0	BARE ROCK
File 1	Theme 6	524981	131245.3	6.1	MARSH AND FENS
File 1	Theme 7	2360210	590052.5	27.4	TREED BOGS
File 1	Theme 8	283898	70974.5	3.3	RECENT BURNS
File 2	Theme 1	840875	210218.8	9.8	PINE
File 2	Theme 2	1497	374.3	0.0	COMMUNITIES
		290261	72565.3	3.4	UNCLASSIFIED (outside project)
		11234	2808.5	0.1	MULTI CLASSIFIED
		8615150	2078413.8	100.0	TOTAL

6.2 Mapping Accuracy Assessment

The technique used to assess the classification accuracy involved generation of a correlation (confusion) matrix. As Goodenough and Shlien (1974) pointed out, confusion matrices based on the original training data can give only a partial indication of classification success. One of the main reasons being that far too few pixels are examined. To overcome this problem, additional check training areas (ground verification sites) were identified on the satellite image

from interpretation of aerial photography and the forest inventory maps. A total of 196,358 pixels were examined.

The procedure involved identifying numerous check training areas through the ARIES interactive training task. In order to ensure that a proportionate check was performed for each class, a 3% sample of all pixels in each class were chosen. After all the check training areas were selected, the manual theme generation program was used to "fill in" the training area polygons with pure theme pixels for each respective class as should have resulted from a perfect classification. The third step in the process initiated a theme compare task in which all the selected pixels in the check training areas were compared to the same pixels from the final classification results. Any discrepancies which occur were printed in a confusion matrix (Table 4). Average accuracy of the classification was 87%.

TABLE 4: CONFUSION MATRIX FOR CLASSIFICATION ACCURACY ASSESSMENT

Manual theme files: ELWTTMT01
ELWTTMT02

Classification theme files: ELWTTNEW1
ELWTTNEW2

	DECIDUOUS	TREED ROCK	WATER	SPRUCE	ROCK	MARSH	BOGS	BURNS	PINE	TOTAL	% ACCURACY
DECIDUOUS	8815	55	37	110	0	132	828	115	97	10189	86%
TREED ROCK	24	22823	33	639	240	193	1467	5	1264	26688	85%
WATER	1	3	27793	0	0	36	1	25	24	27883	99%
SPRUCE	89	2190	60	17064	28	50	2564		531	22576	75%
ROCK	4	317	17	0	6610	522	211	2	5	7688	85%
MARSH	0	61	11	143	1548	19746	1608	27	0	23144	85%
BOGS	319	487	1	546	10	1249	36624	0	30	39266	93%
BURNS	46	320	45	80	0	13	251	23021	867	24643	93%
PINE	70	834	72	340	0	225	287	265	10216	12309	82%

Total number of classification pixels = 8,324,889

Total number of pixels used for accuracy assessment = 194,386
(Manually classified in check training areas)

Horizontal axis: classifier theme file

Vertical axis: manually classified check training file

6.3 Class Breakdown Of Results

1. Deciduous forest classified well (86% accuracy). Errors were fairly evenly distributed between the other classes.

2. Treed rock scored 85% accuracy with most of the error committed to the bog and pine class. This would be expected because in the outlining of check training areas, no attempt was made to eliminate scattered pixel groups of other cover in this type of heterogeneous environment. The significance of this class is the ability to differentiate sparse conifer from the more commercially desirable dense stands.

3. The water class posed no problem. Lakes as small as four pixels were easily classified. Narrow rivers, one pixel wide and less were inconsistently classified because of the influence of tree cover on the banks and also because the pixel only covered a portion of the river. Disjointed sections were often manually classified in order to improve cartographic aspects of the maps.

4. Spruce forest stands scored the worst accuracy, 75%. Most confusion occurred with treed bogs which is understandable since that class is primarily composed of small spruce.

5. The bare rock class with an accuracy of 85%, had a large percentage of its confusion pixels committed to the marsh class. An examination of the satellite image revealed that certain marsh areas exhibited very bright tones from the dead or dying reeds and marsh grass. This spectral overlap was also evident in the scattergrams.

6. The marsh class naturally had commission pixels assigned to the bare rock class because the reverse held true for the latter. The bulk of the other misclassified pixels fell into the bog class, a situation which is not unexpected because of similar characteristics between these two themes.

7. Treed Bogs were spectrally very unique and consequently were well classified with a 95% accuracy. Fringe areas of these bogs can contain areas of spruce which may have been classified separately on the forest inventory maps.

8. Recent burns, because of their low spectral response in Band 7 were easily classified. Randomly misclassified pixels were a result of small pockets of unburnt vegetation which were not easily removed when drawing the check training areas.

9. The pine class was more correctly labelled mixed dense conifer (pine dominant) on the thematic maps. Through the process of delineating check training sites, it was discovered that stands of mixed conifer such as pine/spruce or pine/ tamarack consistently were grouped in the pine class. It is believed that the cause of this was related to the absence of a mixed conifer class. Attempts were made at incorporating this class into trial

classifications which resulted in too much overlap into the spruce and pine classes. Subdividing one hierarchy of a class (conifer) into many sub-classes is often expecting too much from a sensor such as LANDSAT. One of the primary objectives of the study was to isolate spruce which was accomplished with reasonable accuracy. Some of the confusions between classes such as the conifer divisions are relatively unimportant because all of these classes are components of one land cover class, e.g. conifer.

10. The cutover class posed a special problem for many reasons. Old cutovers rapidly rejuvenate with an influx of aspen and result in these areas being classified in the deciduous class. Other cutting activities conducted on bedrock environments were confused with the bare rock class or the treed rock class, if selective cutting was practised.

Literature reviews indicate that the most accurate method of mapping cutover areas is through multi-temporal analysis. Banner and Lynham (1981) describe a multi-temporal approach for mapping cutovers. Two band five overlays of different years of data are loaded through the red, green and blue colour guns of the T.V. monitor. Because of the absence of vegetation on the later image date, the cutover areas appear as distinct blue-green areas on the overlay image. Supervised training sites are subsequently developed for supervised classification.

11. The urban class which was added to the maps through manual theme generation, would be meaningless to include in the confusion matrix.

It is inevitable that the land cover types are generalized when they are limited to a range of 10 categories as used in this study. This number of classes however, is considered to impose a practical level of generalization. More detail not only results in a confusing image (cartographically), but introduces a greater possibility of error into each, more specific theme.

7.0 DISCUSSION AND SUMMARY

The regional reconnaissance level overview that the analysis of LANDSAT imagery provided proved to be an extremely important component of the planning process. The intent of the initial project request from Parks Branch was to use LANDSAT imagery to help identify the range of representative landforms and cover types on the east side of Lake Winnipeg and then to chose as complete a set of representative landscapes as possible adjacent to the superlative whitewater river corridors in this region, with the intent of identifying a park area which would have high natural as well as recreational values.

Background data reviewed in advance of the LANDSAT analysis indicated that the natural values of the study area were among the most significant of their kind in North America. Past surveys had indicated that a wide range of both rare and representative species of flora and fauna and a wide range of Canadian Shield landforms had been identified here. The need to retain these values in an unaltered natural state was of prime importance. Park placement, therefore, had to take into consideration each habitat - altering projects as future roads, transmission lines and forestry potential and avoid or reduce

the impact of those activities on the park area ultimately designated.

While transportation corridor routes and other social factors were generally known, timber harvest specifics such as the regional distribution of the favored species, spruce, and location of cover types and landforms were for the most part not documented. This information would be of critical importance in discussion with the forestry industry if a preservation - oriented approach for park designation, which would preclude roads or cutting areas within the park, was to be implemented.

The imagery was successfully classified, and the resulting map of cover types proved to be an excellent basis on which to begin final discussions regarding areas to be included within a park boundary. These high quality, accurate and aesthetically pleasing maps were used constantly in presentations- literally from the day they were received. The advantage in having this type of relatively detailed information available for not only the area of greatest concern but for also surrounding regions was inestimable throughout the planning process. Of particular value was the ability of the imagery to be resolved into generalized thematic groups so that the distribution and significance of each could be readily and quickly explained to an individual not already familiar with the area. Discussions included "trade offs" of areas with high timber potential for areas having high habitat potential as identified by other sources and or inferred by the LANDSAT imagery. While some of the final decisions were based upon social and economic concerns rather than solely the resource base, these decisions could at least be made in the overall context of the spatial distribution of the source area.

The final result of the overall regional review was a park configuration (Figure 9) which included exceptional examples of nearly all the representative natural values identified in the region, yet avoided the majority of potential conflicts such as road corridors and key forestry potential areas. This park area has been confirmed as the area best suited for ongoing representation of the boreal forest region within Manitoba's park system, and the overall role of the park will be to maintain the existing regional values in as natural and unaltered state as possible.

Two subsequent courses of action are now being pursued. One is an information/participation program through which the views of the public on both the maintentance of the natural and cultural values and how the park can best be managed to the benefit of regional centres and businesses given the overall role of the park. The other is a continuing program of resources inventory leading to a fuller understanding of the natural resources of the park, and through this understanding, the ability to constantly improve management of the activities which will be taking place within the park.

Parks Branch is very excited about the prospects of continued use of LANDSAT imagery, using different interpretation techniques to assist in the inventory/management process. The next use of this technology will be to assist in the identification and definition of distribution of wildlife habitats in the park and surrounding area.

The ability of this park to provide meaningful social and economic benefits to Manitobans in the future depends heavily upon the continued public involvement by area residents, business operators and

recreation users, and upon the ability of the Parks Branch to effectively monitor the state of the natural resource base of the park. Parks Branch fully expects that as the quality and resolution of satellite imagery improves, and the application of technology advances, that this type of remote sensing will become increasingly important to management of this and other Provincial Parks emphasizing the values of the natural environment in the future.

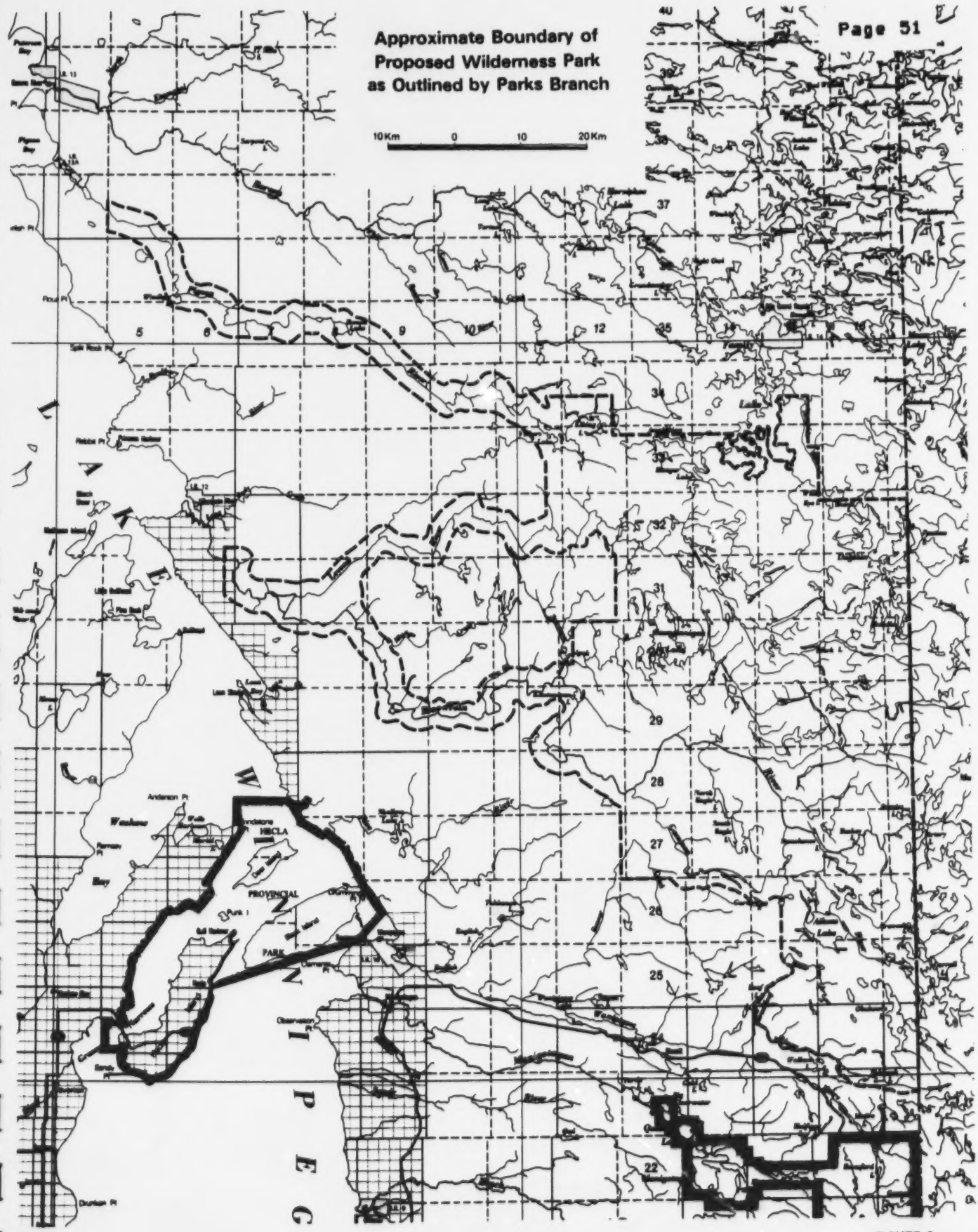
Approximate Boundary of
Proposed Wilderness Park
as Outlined by Parks Branch
10Km 0 10 20Km
LAKE WINNIPEG
HECLA
PROVINCIAL
PARK

FIGURE 9

In short, the benefits of this information gathering approach to the planning process were:

1. The information obtained was comparable in accuracy to other more laborious means.

2. The information gathering process was fast and quite inexpensive.

3. The process resulted in a professional quality, highly attractive, high impact, easily readable product.

4. This was probably the only technique that could have been used to supply the information required in the time frame available.

   This approach enabled planners to not only study areas of special interest but also relate the land cover types within this area to those of other areas in the region. This proved to be of vital importance in the inter-agency discussions which were a critical part of the planning process.

5. This approach reduces the need for additional staff within the Parks Branch and helps maximize efficiency of existing staff involved in this project.

6. The greatly increased ability to assess areas of interest has significantly increased the quality of the planning product and will allow the Parks Branch to more fully and effectively meet their public mandate.

8.0 RECOMMENDATIONS/FUTURE ACTIONS

On the basis of this study the following recommendations should be considered:

1. This information should be obtained for all major provicial natural areas to aid in master planning thrusts and to provide a permanent record of manipulated or evolutionary changes in a park or other natural areas land base/ resource.

2. That LANDSAT information should be obtained for all significant areas under consideration for future park use so that initial reconnaissance of these regions can be aided through information gained by means of supervised classification techniques.

3. Means of further enhancement of this information (through addition of contour information, etc.)should be pursued.

4. The integration of this information into habitat management and facilities impact and placement should proceed quickly.

5. Use of the new high resolution imagery expected from the LANDSAT thematic mapper and the French SPOT satellites should be evaluated as soon as it is available for other areas of Parks Branch interest.

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APPENDIX NO. 1

MEMORANDUM OF UNDERSTANDING

Between

The Department of Natural Resources of the Government of Manitoba

and

The Department of Energy, Mines and Resources of the Government of Canada

for

COOPERATION IN REMOTE SENSING

ARTICLE I. Scope and Objectives

The Department of Natural Resources of the Government of Manitoba (hereinafter referred to as DNR) and the Department of Energy, Mines and Resources, Government of Canada (hereinafter referred to as EMR) hereby state their intention to pursue scientific and technical cooperation in remote sensing in accordance with this Memorandum of Understanding (hereinafter referred to as "Memorandum") which establishes the procedure for cooperation.

The purpose of this Memorandum is to establish a framework for enhancing the scientific and technical capabilities of the Government of Manitoba in the application of remote sensing technology to natural resource management activities. EMR and DNR (hereinafter referred to as Parties) will undertake to implement a joint technology enhancement program as described in Schedule A. It is understood that EMR may include the cooperation of personnel from other federal government departments to provide specific scientific and technical capabilities pertinent to the projects being undertaken in the program.

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ARTICLE II. Responsibility of the Parties

EMR will use its best efforts to: (i) have available for consultation a remote sensing specialist during the term of this Memorandum to assist provincial personnel engaged in demonstration projects; and (ii) provide training to provincial personnel in the use of the image analysis system lent to DNR. In addition, EMR will use its best efforts to give priority consideration for the use of image analysis facilities and remote sensing aircraft of the Canada Centre for Remote Sensing during the term of this Memorandum for the purposes of this cooperative endeavour.

DNR will endeavour to: (i) provide office accommodation for federal personnel engaged in the program; (ii) schedule, operate and maintain the image analysis system in accordance with the loan agreement, and (iii) coordinate the activities of provincial agencies involved in the demonstration projects.

The Parties will jointly define the objectives, resource requirements, and criteria for evaluation of specific demonstration projects. Changes to project design or the initiation of new projects will be undertaken only after consultation between designated representatives mutually acceptable by the Parties. Responsibilities of the Parties are detailed in Schedule A.

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ARTICLE III. Source of Funding

Cooperative activities under this Memorandum will be subject to, and dependent upon, the financial support and manpower available to the Parties. Each Party will pay all operating expenses of its employees engaged in the program. DNR will use its best efforts to acquire satellite and airborne remote sensing imagery required for the projects, from Canada in accordance with its standard rates and to provide office accommodation for the program in Winnipeg.

ARTICLE IV. Review of Activities

The technology enhancement program established by this Memorandum will be monitored and evaluated by interdepartmental committees at the federal and provincial level. A federal Technology Enhancement Review Board, chaired by EMR, includes representatives of Agriculture Canada and Environment Canada. A provincial Advisory Committee, consisting of directors of the branches of provincial departments involved in the demonstration projects, will make recommendations to DNR on the nature of a provincial follow-on program when this Memorandum expires.